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APPARATUS FOR TESTING COMPUTER MEMORY

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APPLICATION PAPERS

OF

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FOR

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APPARATUS FOR TESTING COMPUTER MEMORY

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## APPARATUS FOR TESTING COMPUTER MEMORY

5 The present invention relates generally to an apparatus for testing computer memory and particularly to an apparatus for testing large capacity, wide data bus width memory such as Dynamic Random Access Memory (DRAM).

### BACKGROUND OF THE INVENTION

10 As will be familiar to those skilled in the art, Dynamic Random Access Memory (DRAM) is a type of RAM that has high-density storage, but requires regular refreshing of its contents. Conventional test systems for DRAM utilise three typical designs. For example,  
15 the test system may utilise the hardware with which the DRAM is designed to operate, running special test software. Alternatively, a processor system may be employed to test the memory at full speed and all at once. A third option is to use a lower performance  
20 processor system that tests the memory in smaller pieces.

DRAM modules requiring test may have a wide data bus and large capacity. This is particularly the case when the DRAM is designed for a large system such as a  
25 file server or workstation. Testing a large capacity, wide data bus DRAM using the first two systems set out above is therefore expensive, because of the cost of the processor technology required to access the memory. The third system, although cheaper, starts to  
30 compromise on test speed and coverage.

It is an object of the present invention to address these problems with the prior art.

### SUMMARY OF THE INVENTION

35 According to a first aspect of the present

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invention, there is provided an electronic memory device tester, comprising: an input, arranged to receive seed data which has a first number,  $p$ , of seed data bits, from a computer; and a data generator  
5 arranged to generate an array of prepared data having a second number,  $q$ , of prepared data bits, where  $q > p$ , and arranged to generate from the prepared data a test data pattern for writing to an electronic memory device to be tested.

10 The tester generates its own test patterns thus relieving the computer processor from that task. This in turn allows the computer to control the test cycle itself without compromising test speed. Thus, a slow cheap processor may be employed to test fast RAM  
15 designed for expensive computer systems. The invention also extends to a method of writing data to an electronic memory device to be tested, comprising the steps of: (a) generating, in a separate computer, seed data having a first number,  $p$ , of seed data bits; (b) receiving, in a memory tester, the seed  
20 data; (c) generating, from the received seed data, an array of prepared data having a second number,  $q$ , of prepared data bits, where  $q > p$ ; (d) generating, from the prepared data, a test data pattern; and (e)  
25 writing the test data pattern to the electronic memory device to be tested.

In summary, the present invention provides a DRAM test system utilising a low performance central processor system connected using a standard PC104 bus  
30 system to a set of control logic that is capable of generating test patterns and sequences and controlling access times and parameters. The control logic forms the core of the invention providing full speed and full bus width access to the DRAM. It is capable of  
35 reading, writing and verifying data patterns to the

DRAM and reporting the results back to the processor. Both fast page mode (FPM) and extended data out (EDO) DRAM types can be tested and provision is made so that any other types of RAM could be tested such as Static  
5 RAM (SRAM) and Synchronous DRAM (SDRAM).

The logic system does not compromise test coverage as a typical memory tester could. A typical memory tester will multiplex a smaller data bus to enable the low performance processor to access a much  
10 wider bus than it was originally designed for. The present invention uses its core logic to access the whole data bus of the memory under test at once. The processor can program the required data patterns, read back information that has been read from RAM and  
15 command the logic to perform various functions, but has no direct interaction with the RAM, relying instead upon the core logic to verify results. This means that the memory module is tested as a whole, increasing fault finding by simulating the DRAM target  
20 system. Also the overall time to test a module is faster as no repetition is required as would be if multiplexing were used.

#### BRIEF DESCRIPTION OF THE DRAWINGS

25 The invention may be put into practice in a number of ways, one of which will now be described by way of example only and with reference to the following drawings, in which:-

Figure 1 shows a schematic block diagram of a  
30 test system embodying the present invention;

Figures 2a and 2b show a flow chart of the operation of the test system of Figure 1;

Figure 3 is a block diagram showing the computer system of Figure 1 in more detail;

35 Figure 4 is a block diagram showing the data

Figure 5 is a block diagram showing the test pattern generator of Figure 1 in more detail;

Figure 7 is a block diagram showing the data read registers of Figure 1 in more detail;

Figure 10 is a block diagram showing the DRAM cycle controller of Figure 1 in more detail.

Referring to Figure 1, a functional block diagram of a memory test system 127 embodying the present invention is shown. The system is controlled by a computer system 100 employing, for example, a V20HL microprocessor. A detailed diagram of the computer system 100 is shown in Figure 2 and will be described in detail below. As seen in Figure 1, the system is arranged to test a memory module 108.

The computer system 100 controls the test system 127 by means of data written to a system bus 110 using direct port output commands and memory write commands. The test system 127 tests the memory module 108 using a memory module bus 111. The results of tests carried out by the test system 127 are read back by the computer system 100 using input port commands and memory read commands. The test system 127 includes data write registers 101 for loading a "seed" (typically a single data byte) for a test pattern into a test pattern generator 102. The seed is obtained from the computer system 100 on partial write data

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system will now be presented.

The test system 127 is firstly powered up by connecting it to an external power supply (not shown). An internal battery could of course be used instead.

5 Next, a memory module 108 to be tested is inserted into a socket provided in the system. Suitable software running on the computer system 100 then initiates a user-selected test, at step 1000 of Figure 2a. To begin a test the following parameters  
10 need to be set in the computer system 100, and this is carried out at step 1010.

Firstly, the refresh rate of the system (which is dependent upon the refresh rate of the computer system 100 and that of the memory module under test 108) are  
15 specified. Secondly, the computer system 100 is informed of the capacity of the memory module 108, together with the data bus width of the memory module 108.

The software also allows the access cycle time, the RAS/CAS delay time, the RAS/CAS enable  
20 requirements, and the output/write enable requirements to be programmed into the DRAM cycle controller 107 from the computer system 100. The RAS/CAS enable requirements are defined by the number of RAS/CAS  
25 lines the memory module requires, and the output/write enable requirements are defined by the number of output/write enable lines the memory module requires.

Once these parameters are set, seed data can be loaded into the data write registers 101 from the  
30 computer system 100. The data write registers 101 grow the seed data into prepared data which is written to the test pattern generator 102 (step 1020). A test pattern mode is then selected in the test pattern generator 102 by software in the computer system 100,  
35 as shown at step 1030. The upper address lines are

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117. In order to verify the read success, the

computer system 100 obtains a pass/fail signal 116  
from the data comparators 103, via the system bus 110  
and a pass/fail signal port (not shown in Figure 1).  
One full cycle completes upon receipt of the pass/fail  
5 signal 116.

The use of the error signal 118 to freeze the  
data read registers 104 when an error occurs allows  
the computer system 100 to continue driving write  
cycles without obtaining pass/fail data 116 on every  
10 cycle. This allows the computer system 100 to use a  
small, fast write loop in software to drive the write  
cycle and then check the pass/fail data after a burst  
of cycles. Typically a burst of consecutive read and  
write-signals are transmitted and received, over a  
15 range of addresses covered by the lower address  
signals 128, until the end of a memory mapped region  
is located. When the upper address registers 105 need  
to be updated, the pass/fail signal port may be polled  
to determine if any errors occurred during the burst  
20 (step 1090). This increases the test speed of the  
system overall, as the computer system 100 (which is  
usually slower than the test system 127) is only  
required to perform two simple operations (write/read)  
in a loop.

Upon checking a valid error signal 208 (described  
further in connection with Figure 6), if no errors are  
located (at least for that memory mapped region), then  
the computer system 100 writes an incremented address  
to the address registers, at step 1100. If the end of  
30 the addressable region of the memory module is  
reached, then the test procedure completes and  
indicates a PASS for the memory module at step 1110.  
Otherwise, the procedure reverts to step 1050 (Figure  
2a), so that the next memory mapped region is tested.

35 If, on the other hand, the error register

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table below.

It will be understood that these signals are widely used in a number of common computer systems.

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TABLE 1  
SYSTEM BUS SIGNAL DESCRIPTIONS

	<u>Signal</u>	<u>Use in the embodiment of Figure 1</u>
5	MRFRSH	Memory refresh (holds system during a refresh cycle)
10	IO	The type of address request is an input/output request
15	MEM	The type of address request is a memory access
	DO-1	Data bus signals
20	A0-20	Address bus signals
	RD	Access type is read
25	WT	Access type is write
	MRAS	Memory row address strobe signal
30	MCAS	Memory column address strobe signal

Referring next to Figure 4, the data write registers 101 of Figure 1 are shown in more detail.

35 The data write registers comprise a plurality of data latches 101.0, 101.1, 101.2 ... 101.X, one byte each, that are accessible individually by the system bus 110 using system data bytes 171. Each data latch is able to load a corresponding latch data byte 174.0, 174.1, 40 174.2, ... 174.X onto a prepared data line as prepared data 124, to be sent to the test pattern generator 102. The output of an  $n^{\text{th}}$  data latch 101.n is also used as an input to the subsequent  $(n+1)^{\text{th}}$  data latch

101.n+1.

In the preferred embodiment of the invention, 18  
byte wide registers are used to allow for testing of a  
144 bit wide data bus on the memory module. To  
5 prepare the data for the test pattern generator 102,  
the computer system 100 writes individually to each  
latch with a byte, or to all the latches at once  
filling them all with the same data byte using a  
register write selection signal 113. The latter is  
10 the fastest and preferred method. The test pattern  
generator 102 then uses all data bytes in parallel.  
This design allows for a combination of rapid pattern  
preparation as well as the flexibility to write any  
data to the memory module 108 if required. Again,  
15 registers of other widths can be used for different  
data bus widths on the memory module to be tested.

The data write registers 101 may act as shift  
registers. This is a function that is a part of  
pattern generation, but is not carried out in the test  
20 pattern generator 102. As each write is performed,  
the data write registers 101 can rotationally shift  
the data pattern one bit to the left. This allows  
marching test patterns to be performed. For example,  
a binary pattern of all 0's and a 1 as bit 0 may be  
25 loaded into the register. The 1 may then be shifted  
on each write cycle.

Turning now to Figure 5, the test pattern  
generator 102 of Figure 1 is shown in more detail.  
The test pattern generator comprises an exclusive OR  
30 data inverter 186 and a test pattern mode register  
192. With nothing set in the test pattern mode  
register 192, the data present as prepared data 124  
from the data write registers 101 is passed through  
the data inverter 186 and latched into a data register  
35 182 without any shift being performed. This data is

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gate, then an error signal 118 is generated which is then latched at the end of a valid read cycle (flagged by a systems read signal 209) using a valid error gate 207. The latched compare result is output from the valid error gate 207 as a valid error signal 208. The pass/fail signal 116 can be read back by the computer system 100 via the system bus 110 and contains one bit for each group of three bytes (6 bits), allowing a rapid decision to be made on which area has failed. The CPU needs only check that the pass/fail signal is not indicating a failure. This can be done after many "burst" reads from the CPU. Therefore, unless the pass/fail signal indicates a fail, the CPU does not need to read back the data that the tester has read via the "partial read data", at all. The only reason for reading back the partial read data is so that the CPU can display the result of a failure condition.

The valid error signal 208 is fed to the data read registers 104 (Figure 1) and inhibits the registers from latching again until the error is cleared. This takes place when a new piece of data is written to the data write registers 101 using a system write signal 210.

Figure 7 shows the inputs to, and outputs from, the data read registers 104 of Figure 1 in more detail. The data read registers 104 each consist of a 144 bit register that latches the contents of the memory module data bus 111 at the end of a read cycle. The 144 bit register then provides these data upon the memory module data bus 111 to the data comparators 103 as latched read data 126. The system read signal 209 provides a latching signal which is fed through a stop reading error latch 231. The latching signal can be stopped as it is fed through the stop reading error latch 231, which sets when an error is detected via

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the error signal 118. This means that subsequent reads will not pass through the stop reading error latch 231, and the data that failed comparison is held by the latch until the stop reading error latch 231 is cleared by a system write signal 230. This allows for the aforementioned multiple cycles to take place without affecting the data determined to be failure data and then latched. Thus, there is only an output on the valid read signal line 228 when the signal is not frozen.

The contents of the data read registers 104 can be read back to the smaller system bus 110 of the computer system 100 by using a multiplexer 222. The computer system 100 addresses the byte it needs to read back via a data byte selection signal 227 using the system bus 110. The read back byte is presented to the system bus 110 via the partial read data signals 117 described above.

Figure 8 shows the inputs to, and outputs from, the upper address registers 105 of Figure 1. The upper address registers consist of two 8 bit (one byte) wide write only registers 240 and 244. The computer system 100 loads the upper address data 130 into these registers using the system bus 110, effectively extending the addressing range of the CPU for the purposes of testing the DRAM. A register write selection signal 172 selects which of the two registers is to receive the byte from the system data byte 171. For the lower address lines which provide the lower address signals 128 (Figure 1), 12 of the 20 address lines of the computer system 100 are used (from a memory mapped location). Thus the latched upper address 129 extends this to 28 bits (8 bits each from the two write only registers 240 and 244, and another 12 bits from the 12 address lines) giving an

effective addressing range of 256Mb ( $2^{28}$  bytes). With the 18 byte (144 bit) wide data bus this gives a direct addressing capacity limit of  $18 \times 256\text{Mb} = 4.59\text{Gb}$ .

Figure 9 shows the address generator 106 of Figure 1 in more detail. The latched upper address 129, and the lower address signals 128, interface directly to the address generator 106 via a row address selection 251 and column address selection 264 buffers. These combine to form a DRAM address from the linear address. The DRAM memory module 108 is addressed in two parts, i.e. as a row address 254 and a column address 257. To indicate which type of address is being presented to the memory module 108, two signals are used, known as the row address strobe (RAS) and column address strobe (CAS). During a read or write cycle the row address and then the column address are presented to the memory module 108 via the address signals 263 on the memory module bus 256 before data can be read or written. A variable width MUX 255 performs this function.

Depending upon the capacity and type of memory module 108, the way in which the linear address is split into the two parts can vary. The split position should be moved depending upon capacity and it can also be adjusted depending upon whether the module requires symmetrical or asymmetrical addressing. In symmetrical addressing, a 20 bit linear address (for example) would be split into a 10 bit row and 10 bit column address. In asymmetrical addressing, using the same example, the row address might be 9 bit and the column address 11 bit. This requirement is based upon the internal design of the RAM integrated circuits of the memory module 108.

An asymmetrical/symmetrical and address width register (ASAWR) 261 is used to set the mode of

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addressing by the computer system 100 using the system bus 110, the system data byte 171 and the register write selection signal 243, as explained in connection with Figure 8 above. The output of the ASAWR 261 is an address type/size control signal 258 which is used to control the size of the row and column address to be sent to the memory module 108 from the variable width MUX 255. Address widths from 20 bit to 28 bit can be pre-set in steps of 2 bits, with symmetrical and asymmetrical modes for each step, giving a total of 8 selections. Once set up, the address generator 106 passes on the linear address to the memory module 108 in synchronisation with the RAS and CAS signals 121 (Figure 1) from the DRAM cycle signals 119. Thus, the address generator provides improved flexibility for the whole system, as it combines the address on the system bus 110 with the address on the memory module bus (111) in a manner which is transparent to the computer system 100.

Turning finally to Figure 10, a more detailed view of the DRAM cycle controller 107 is shown. The DRAM cycle controller contains those components required to generate the signals for the memory module bus 111, as well as the DRAM cycle signals 119, from the system bus 110. As explained the RAS signals 317 and CAS signals 319 (part of the read/write and control signals 123 shown in Figure 1) are used in the addressing of the memory module 108 and they also govern the overall access time of the memory module 108. This access time is typically a few nanoseconds and the entire cycle is then typically around 60ns. During this, the row and column addresses must be presented and the data read or written from/to the memory module 108.

### Independent enabling and disabling of the signals

is implemented through enable activate registers. An RAS enable active register 313 receives RAS enable data 312 from the system bus 110 together with a register select signal 329 which activates that particular register.

The RAS enable activate register 313 output to an RAS multiplier 316, which also receives an RAS signal from a row address select/column address select generator 306. The RAS control signals 317 are sent to the memory module bus 111 from the RAS multiplier 316.

Likewise, a CAS enable activate register 321 receives CAS enable data 320 from the system bus 110, together with the register select signal 329. A CAS multiplier 318 generates the CAS control signals 319 in response to a CAS signal from the row address select/column address select generator 306 and the output of the CAS enable activate register 321.

A write enable activate register receives output enable data 322 from the system bus along with a register select signal 329. The output is a latched write enable select signal 324 which is fed to a write enable multiplier 325 together with a write cycle signal 327 from the system bus 110. Write signals 326 (again part of the read/write and control signals 127 of Figure 1) are passed to the memory module bus 111 from the write enable multiplier 325.

An output enable activate register 330 is also provided. This receives write enable data 328 along with the register select signal 329. A latched output enable select signal 331 is then generated and used as one input to an output enable multiplier 332. The other input thereto is a read cycle signal taken off the system bus 110. The output enabling multiplier 332 sends read signals 333 to the memory module bus

111.

5 The RAS, CAS write enable and output enable multiplier registers 316, 318, 325 and 332 allow enabling of additional drive lines for memory modules 108 having multiple signal requirements, usually in the case where the memory module 108 is relatively large. In this embodiment, 4 lines each are available for the write signals 326 and the output signals 333, with 8 lines each being available for the RAS control signals 317 and the CAS control signals 319.

10 To govern the access of the memory module 108, two delay lines can be programmed in 0.5nS steps. An access cycle delay line 301 determines the timing of the RAS signal 315 via an access cycle period 302 which is used as a further input to the row address select/columns address select generator 306. Again the access cycle delay line receives the register select signal 329, together with access delay data 300 from the system bus 110.

20 A RAS/CAS delay line 311 similarly determines the time between the start of the RAS signal 315 and the start of the CAS signal 314 via a RAS/CAS period 303, which is used as an input to the row address select/column address select generator 306. RAS/CAS delay data are received by the RAS/CAS delay line 311 along with the register select signal 329.

30 The row address select/column address select generator (RASCASG) 306 provides the control signals on a bus which distributes the DRAM cycle signals to the other sections of the test system 127. Read and write cycle signals 335, 307 are passed on with a DRAM refresh signal 305. The refresh signal 120 identifies when the contents of the memory module 108 are to be refreshed, and all other operations are then halted during that period. The RASCASG 306 also provides a

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During a cycle, the computer system 100 asserts the write cycle signal 307 or the read cycle signal 335. This allows the RASCASG 306 to start the RAS signal 315 and, after the RAS/CAS period 303 has expired, to start the CAS signal 314. After the access cycle period 302 has expired the RAS signal 315 and CAS signal 314 are de-asserted. If the refresh signal 120 on the system bus is asserted, the RAS signals 315 and CAS signals 314 are asserted and all other signals de-asserted during that period. Because the computer system 100 is suspended during this period no conflicting read/write cycle is attempted. This solution makes use of the internal memory control unit (MCU) 156 (Figure 3) of the computer system 100 to suspend all functions during a refresh period. This reduces the amount of logic that would be necessary if an external refresh function were to be used.

The CPU can enable a special heating cycle that can take advantage of the structure of the tester as described above. When this heating cycle is required, the CPU enables a heat cycle latch 610 via a heating enable signal 600. This combines the write cycle signal 327 with the write DRAM cycle signal 307. In this mode, when the CPU commences with a standard write cycle, the write DRAM cycle signal 307 will reinitiate the write cycle signal 327 again as soon as the last cycle is finished. There is no governor to this mechanism so it will free run asynchronously to the standard write cycle until the register is disabled. The cycles repeat too quickly for internal data to be latched successfully by the DRAM, but the logic is still exercised and it is exercised much more

rapidly than normal. The rapid cycle therefore causes the DRAM module to consume more power, which is dissipated as heat. If run over a period of time, the whole memory module will experience a significant  
5 temperature rise above ambient that can then be used, before it cools, during subsequent tests. These tests will be more effective at finding errors due to the higher temperatures having a degrading effect on the performance of the DRAM.

10 Although particular embodiments of the invention have been described herein, numerous variations and modifications will become apparent to those skilled in the art that fall within the spirit and scope of the present invention.

15 Although the aforementioned system and method has been described with respect to testing DRAM modules it will be understood that the method and system described herein is applicable to any logic system that requires a full speed, full bus width test and  
20 must reproduce repeatable responses to test patterns.

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